Exquisitely thin membranes can slash energy spent refining crude oil into fuel and plastic

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Queen Mary scientists have created a new type of nanomembrane that presents a less energy-intensive way to fractionate hydrocarbons from crude oil.

The global production of crude oil is currently around 80 million barrels per day. Hydrocarbons extracted from crude oil are the main ingredients for manufacturing fossil fuels, plastics, and polymers. The process by which they are extracted is extremely energy intensive.

Most refineries process crude oil using atmospheric and vacuum distillation, in which crude oil is heated to separate compounds according to their boiling points. Typical refineries process 100,000–250,000 barrels/day—there are some processing over 1 million. The maximum temperature for the distillation varies based on the quality of the crude, but the distillation temperatures can exceed 500 °C. This process consumes 1100 terawatt-hours per year—nearly 1% of global energy use.

Membrane technology that can separate the molecules in crude oil by their different sizes and classes could be a far more energy efficient process, consuming 90% less energy than distillation columns. Exceptionally thin nanomembranes have proved successful for extracting fresh water from sea water by rejecting the salt while allowing the water to permeate through reverse osmosis (RO) process. The researchers sought to separate hydrocarbons from crude oil by a parallel method.

This requires nanomembranes to be hydrophobic, which can provide high affinity and rapid pathways for processing hydrocarbons. However, conventional nanomembranes used for RO are hydrophilic in nature and exhibit limited permeance of hydrocarbon liquids, remaining too low for industrial crude separation.

A team led by Professor Andrew Livingston at Queen Mary University of London used multiblock oligomer amines to create hydrophobic polyamide nanofilms that provide100 times faster permeance than that of hydrophilic nanofilms. By reducing the membrane thickness to approximately 10 nanometers, they achieved permeance one order of magnitude higher than the current state-of-the-art hydrophobic membranes, with a comparable selectivity in fractionation of real crude oil. As a result, the membranes developed by the team could markedly reduce the energy consumption of processing crude oil. The analysis of the fractionation was performed by ExxonMobil in a laboratory in the United States.

Andrew Livingston, Professor of Chemical Engineering at Queen Mary University of London said, "A vast amount of energy is consumed in industry separating molecules. The aim of our research is to provide low energy alternatives to these processes. Due to the innovations in the chemistry we used to make these membranes, we can achieve molecular architectures that achieve exquisite separations, and provide less resource intensive techniques for the separation of molecules."

Study co-corresponding author Dr. Zhiwei Jiang, research associate at Queen Mary University of London, said, "Thinner is better—the liquid passes through the membranes much more quickly, rapidly speeding up the process, and therefore reducing the plant footprint while processing same quantity of liquids."

The study is published in *Science*.

More information: Siyao Li et al, Hydrophobic polyamide nanofilms provide rapid transport for crude oil separation, *Science* (2022). DOI: 10.1126/science.abq0598.
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